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Ha et al.

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(54) **SURGICAL ROBOT SYSTEM**

(56) **References Cited**

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U.S. PATENT DOCUMENTS

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7,594,933 B2 *	9/2009	Kammerzell	A61B 90/36	600/424
7,747,311 B2 *	6/2010	Quaid, III	A61B 90/36	345/156
8,010,180 B2 *	8/2011	Quaid	.....	A61B 17/1764	600/424
8,374,721 B2 *	2/2013	Halloran	.....	A47L 5/30	318/568.1
8,620,473 B2 *	12/2013	Diolaiti	.....	A61B 19/2203	600/407
8,624,537 B2 *	1/2014	Nowlin	.....	A61B 19/2203	318/560
2002/0120188 A1 *	8/2002	Brock	.....	A61B 90/36	600/407
2002/0165448 A1 *	11/2002	Ben-Haim	A61N 1/36564	600/424
2003/0178964 A1 *	9/2003	Challoner	B25J 9/1694	318/568.21

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FOREIGN PATENT DOCUMENTS

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(57) **ABSTRACT**

A surgical robot system includes a slave device provided with a surgical instrument and a master device to control motion of the surgical instrument. The master device includes a master manipulation module having a manipulation tool, to which a pose recognizer is attached, and a master control module that estimates a pose of the manipulation tool using pose information acquired via the pose recognizer, generates a surgical instrument pose control signal corresponding to the estimated pose of the manipulation tool, and transmits the control signal to the slave device.

20 Claims, 12 Drawing Sheets

(51) **Int. Cl.**

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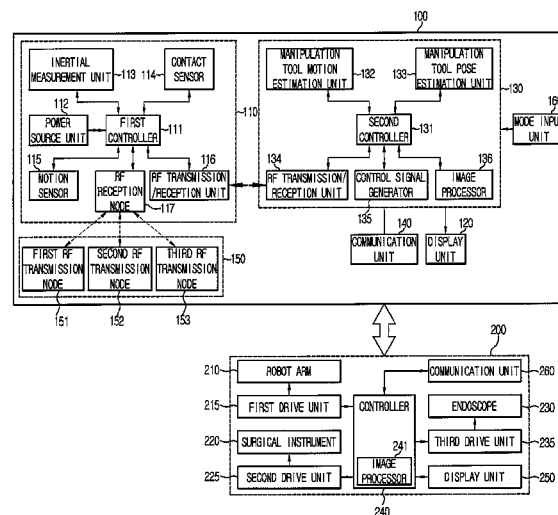
(52) **U.S. Cl.**

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(58) **Field of Classification Search**

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References Cited

2012/0071752	A1 *	3/2012	Sewell	A61B 6/12 600/424
2012/0101508	A1 *	4/2012	Wook Choi	B25J 9/1697 606/130
2012/0221145	A1 *	8/2012	Ogawa	B25J 3/04 700/259
2012/0290134	A1 *	11/2012	Zhao	B25J 9/1697 700/259
2013/0131505	A1 *	5/2013	Daon	A61B 6/481 600/426
2013/0237811	A1 *	9/2013	Mihailescu	A61B 5/064 600/424
2014/0064609	A1 *	3/2014	Petre	G06K 9/6232 382/159
2014/0188275	A1 *	7/2014	Lee	B25J 5/007 700/257
2014/0210986	A1 *	7/2014	Smith	G01N 21/954 348/82
2014/0229411	A1 *	8/2014	Richert	G06N 3/08 706/16

* cited by examiner

FIG. 1

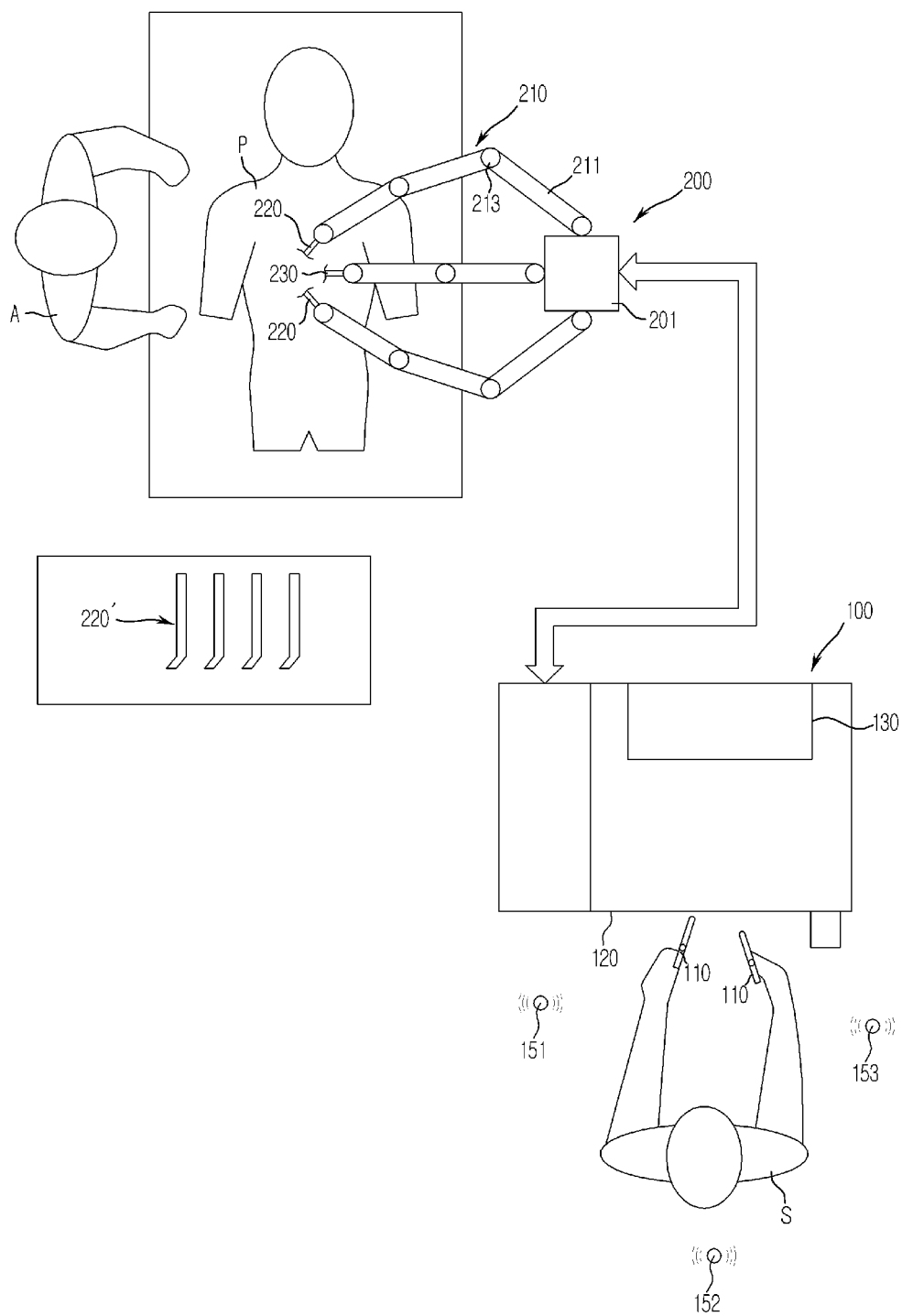


FIG. 2

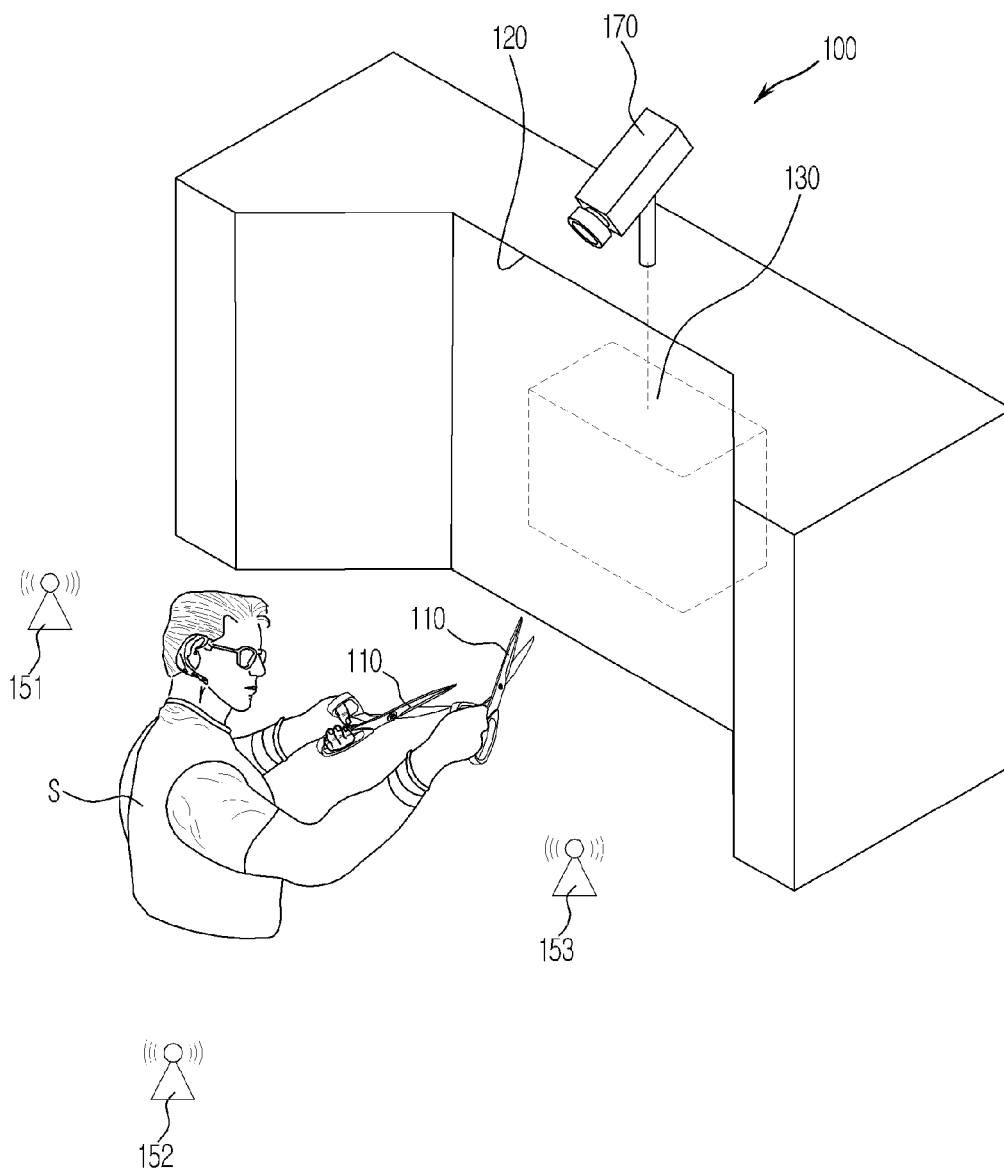


FIG. 3

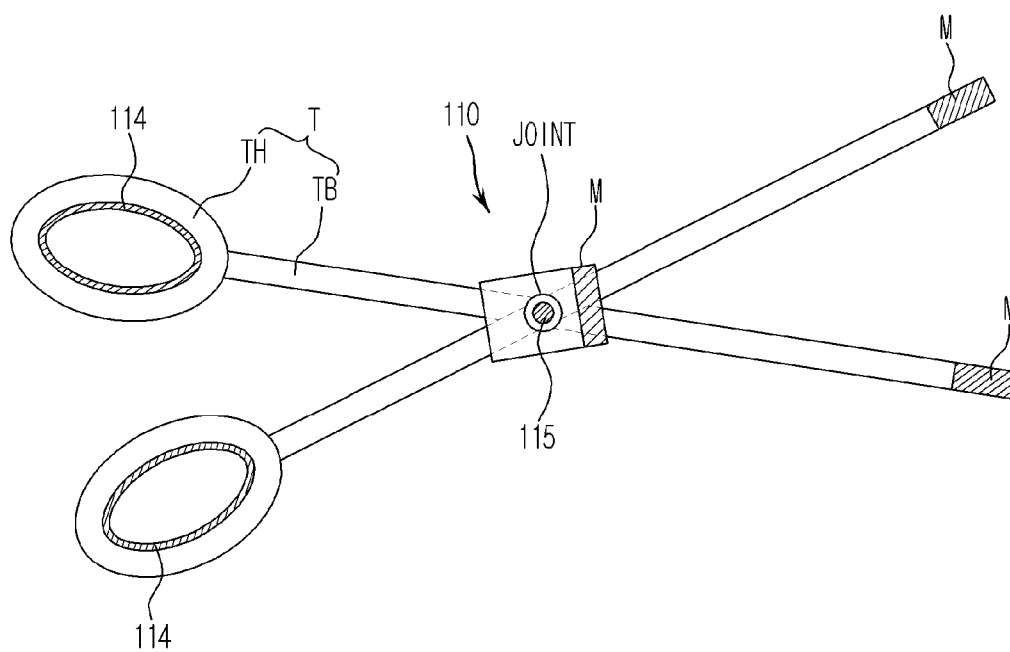


FIG. 4

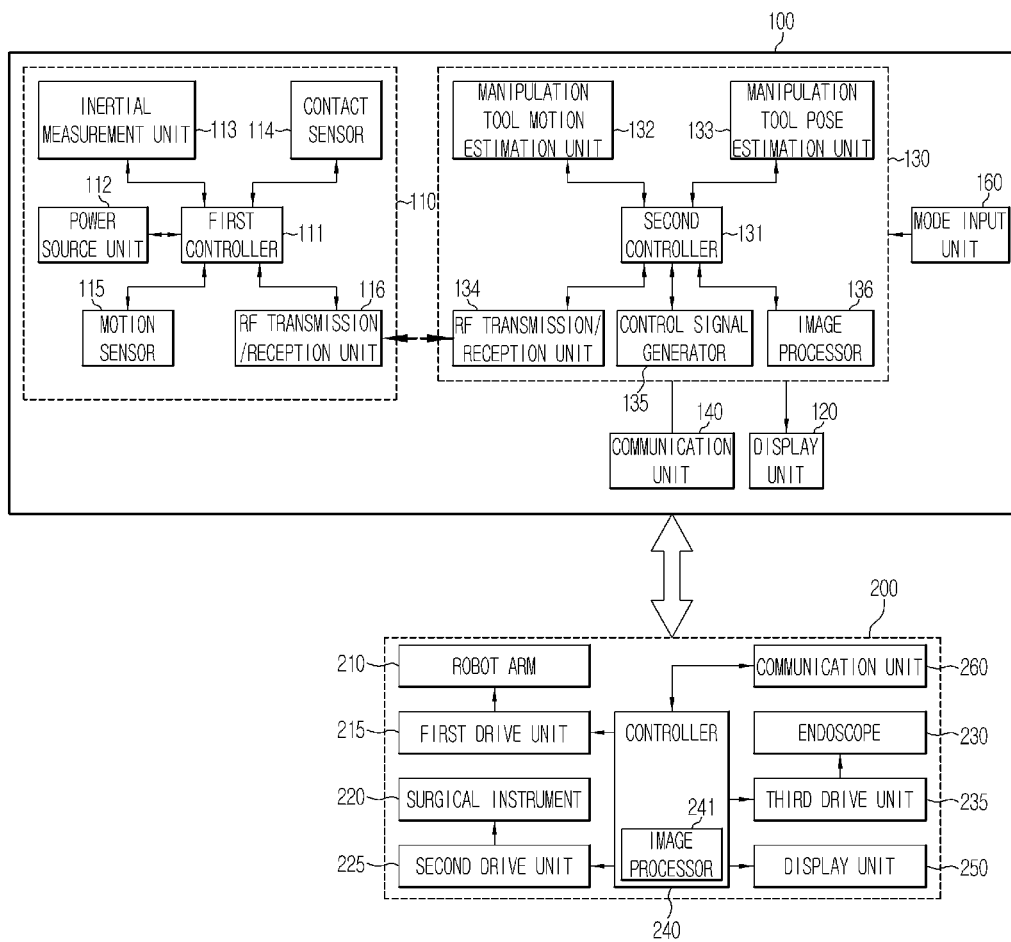


FIG. 5

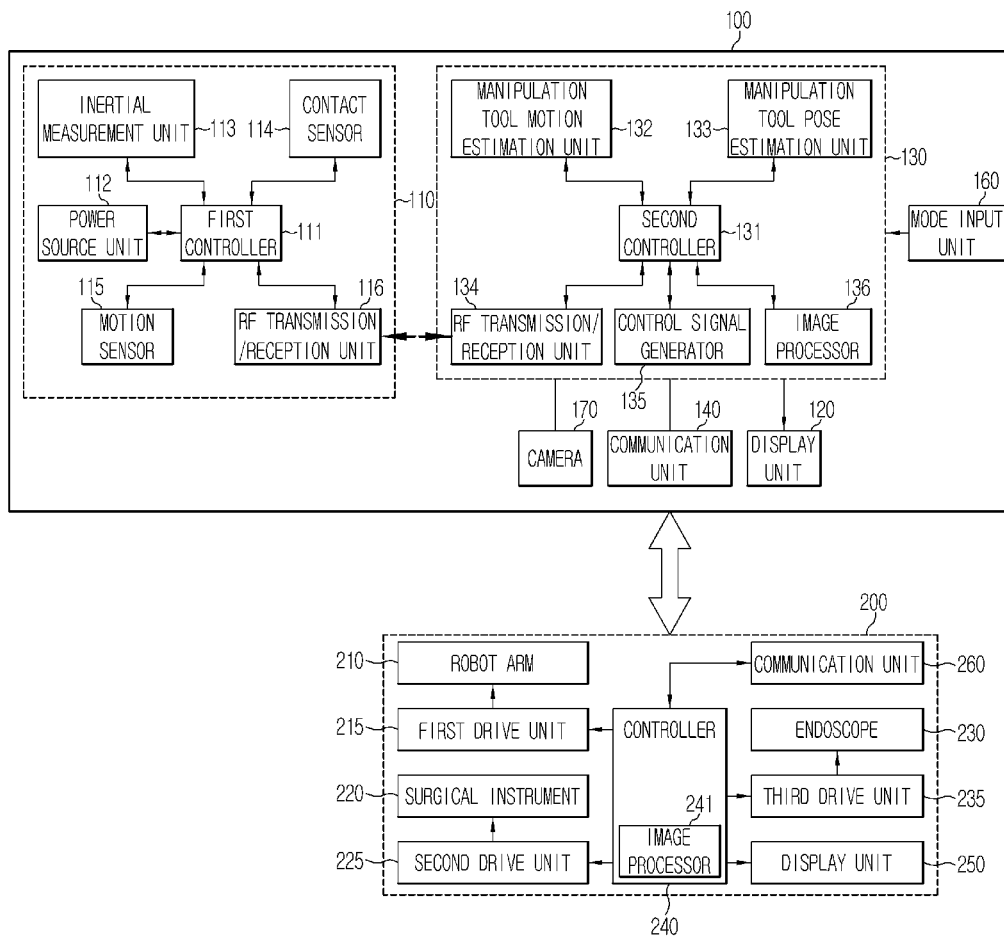


FIG. 6

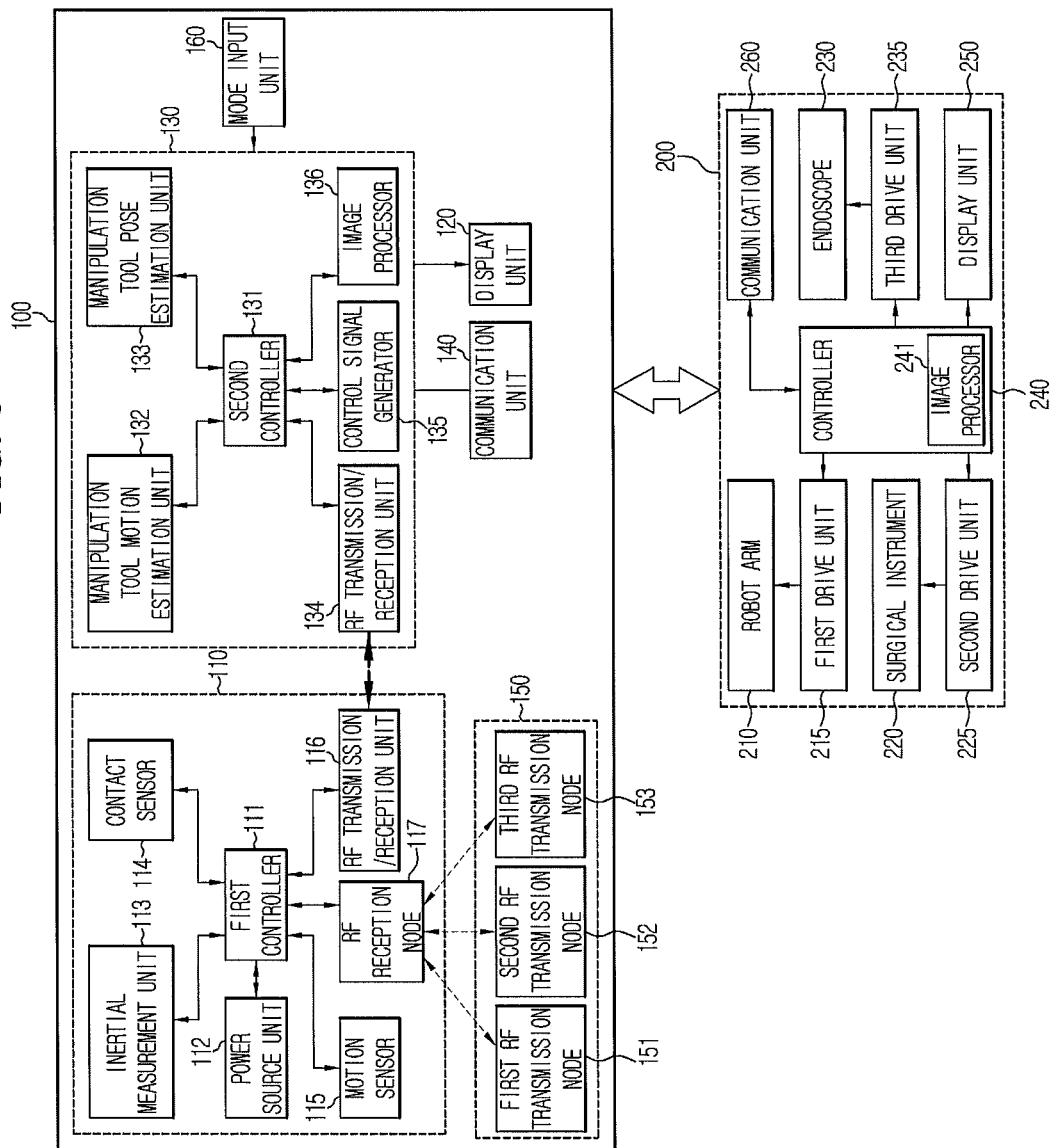


FIG. 7

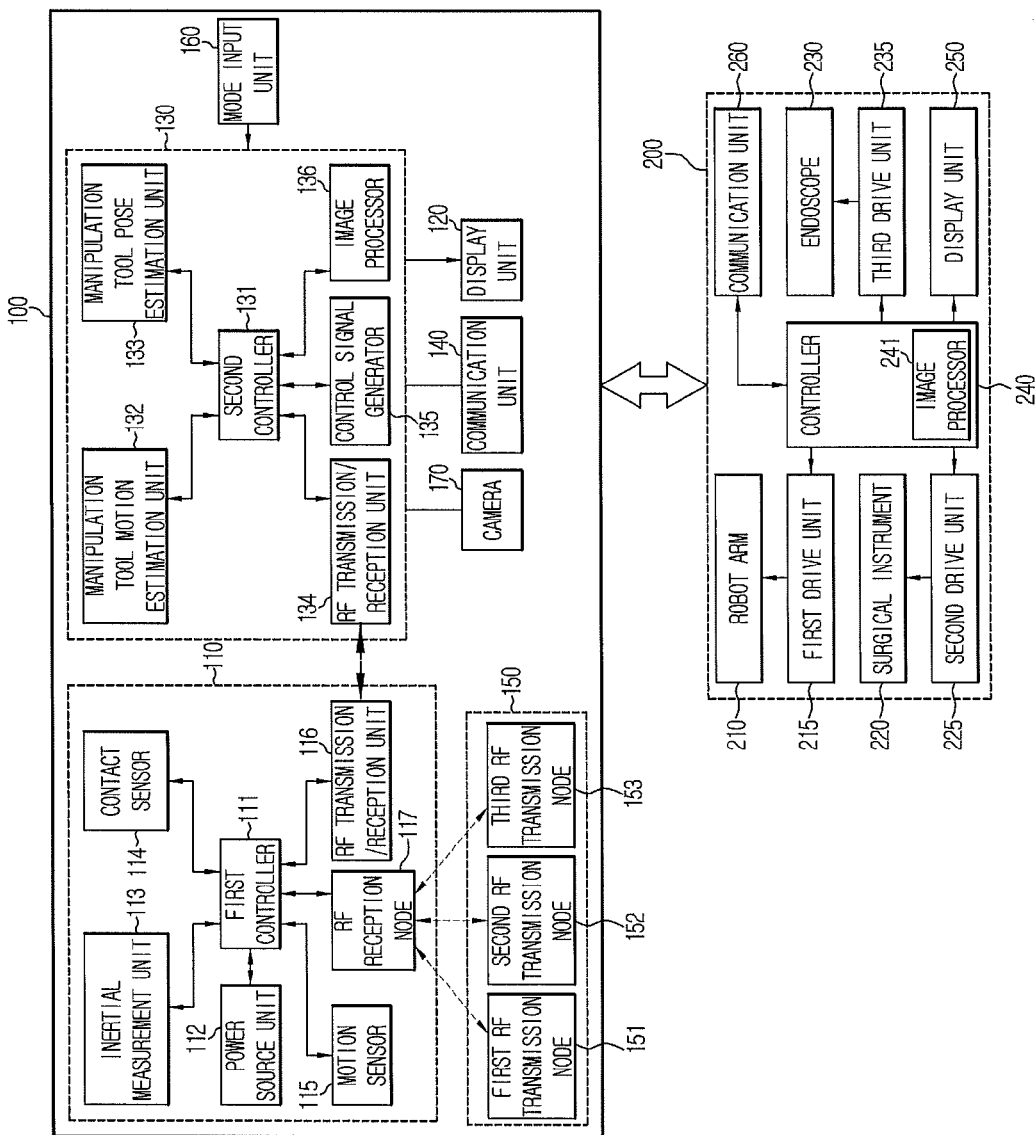


FIG. 8

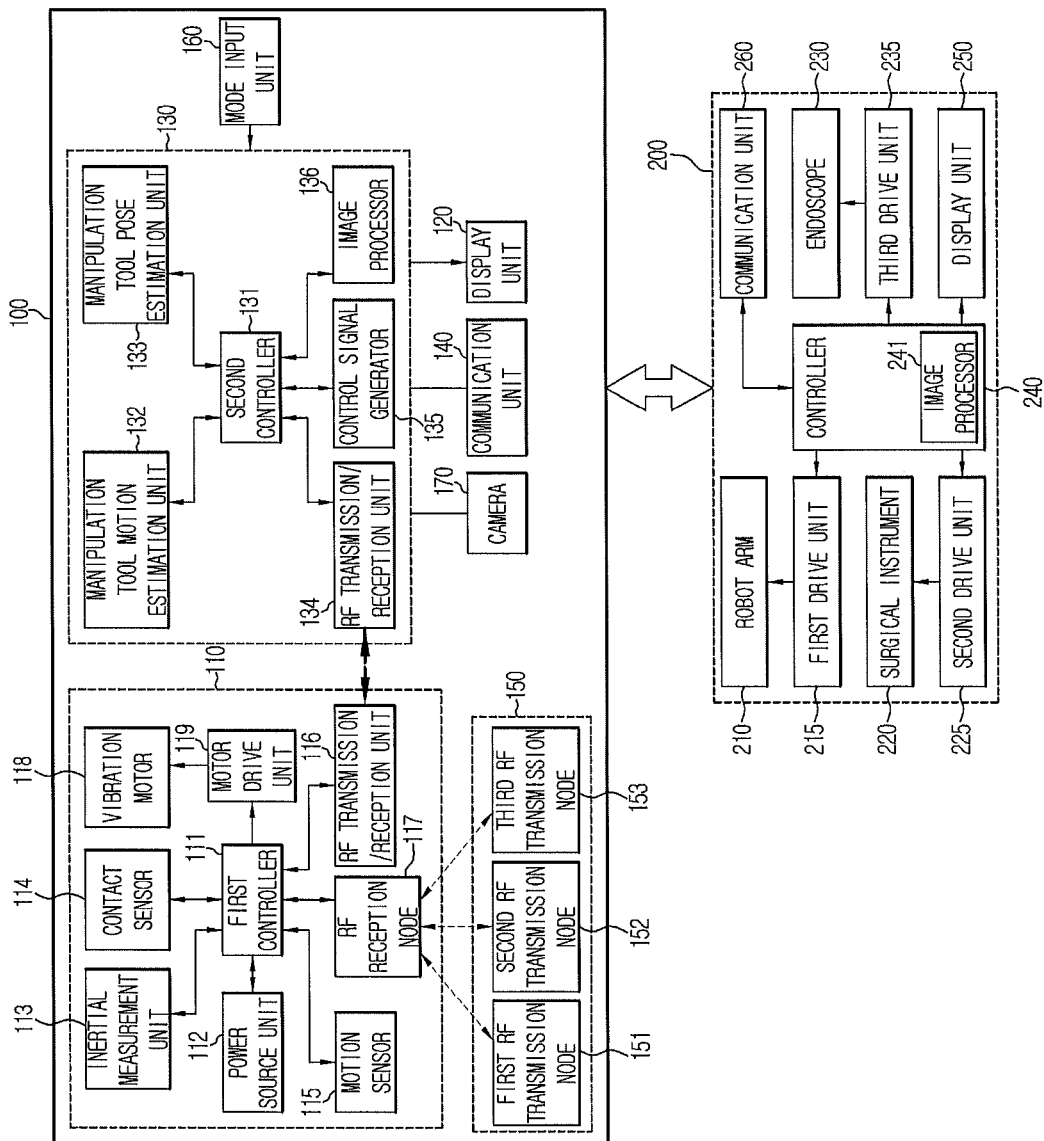


FIG. 9

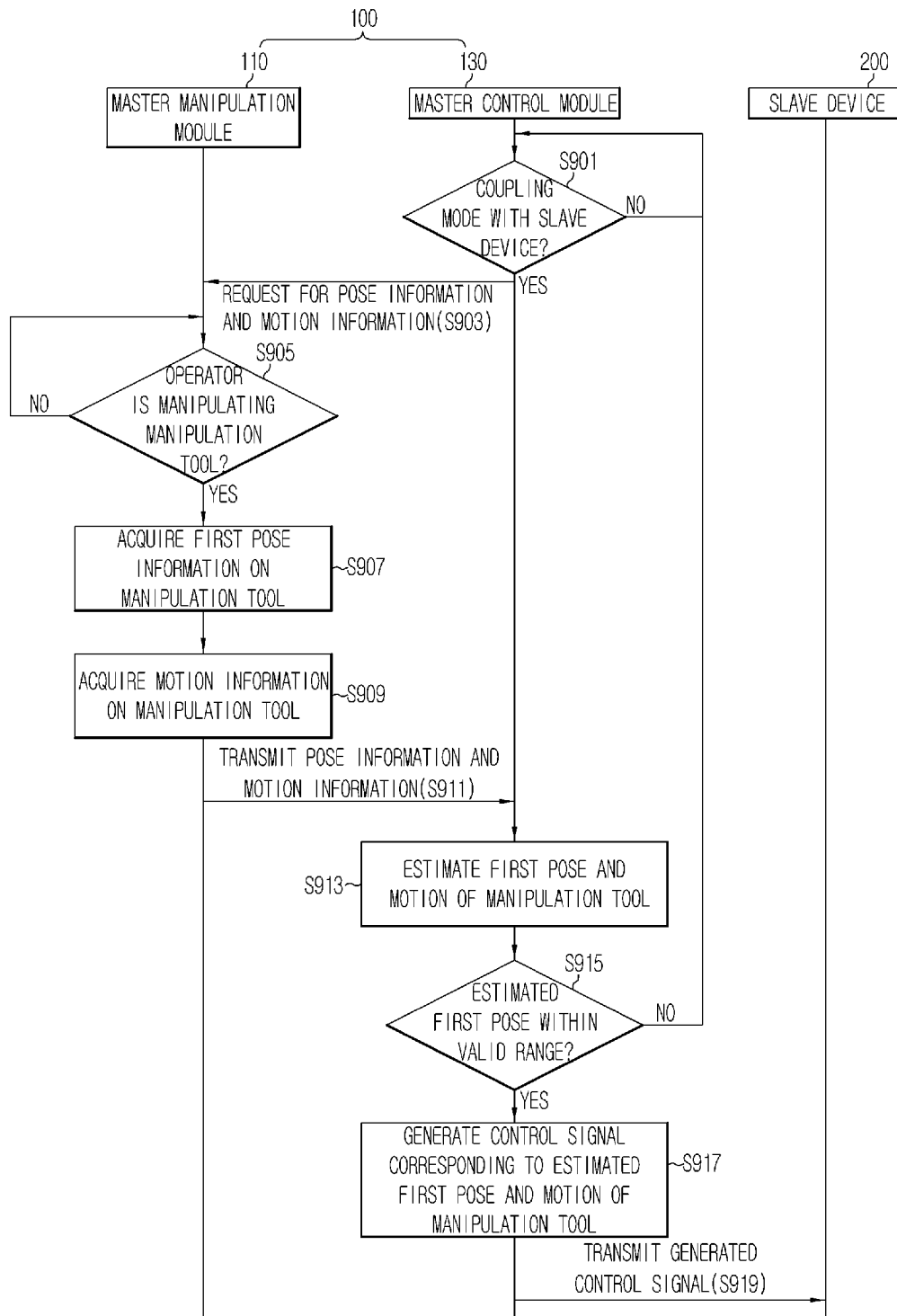


FIG. 10

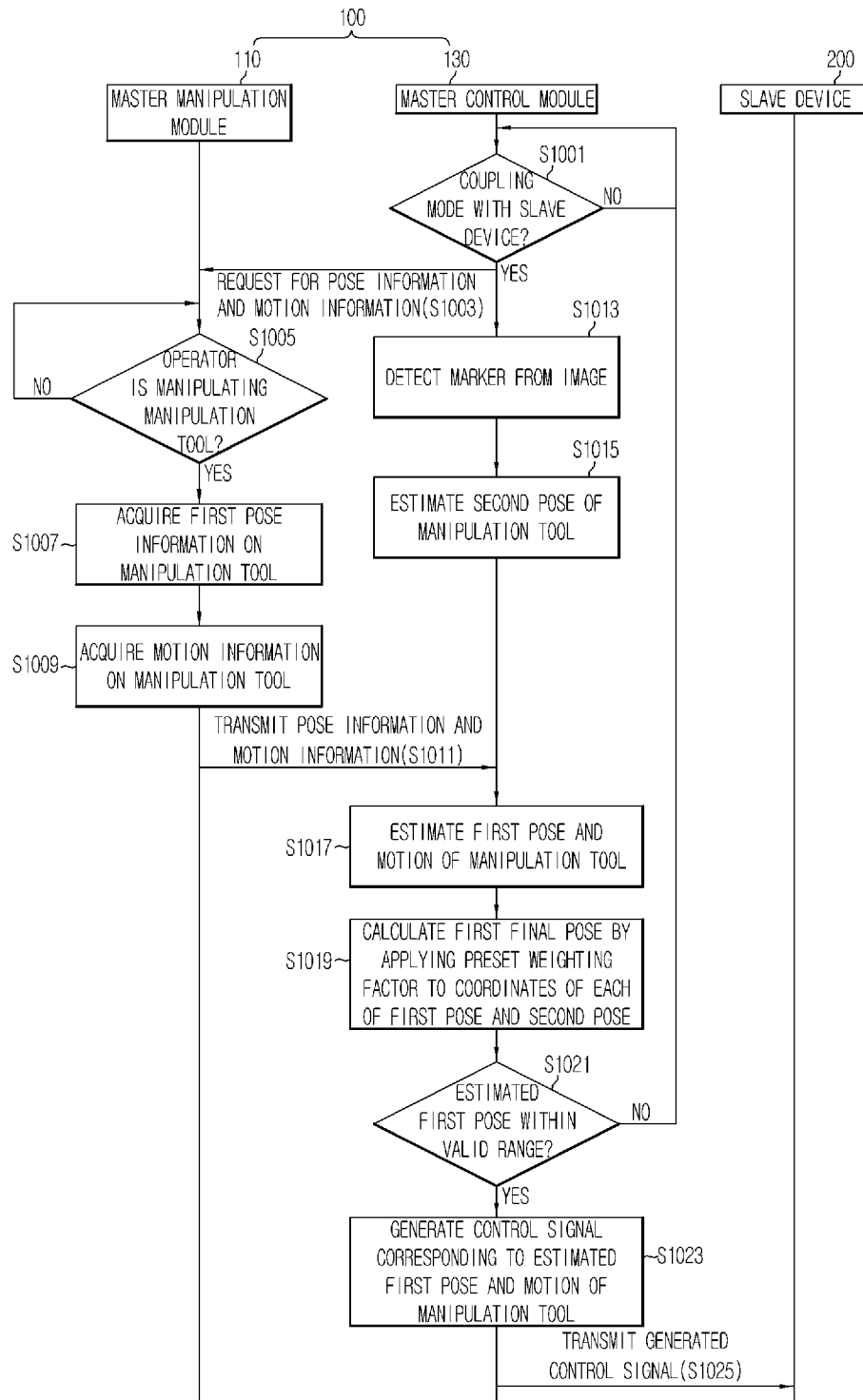


FIG. 11

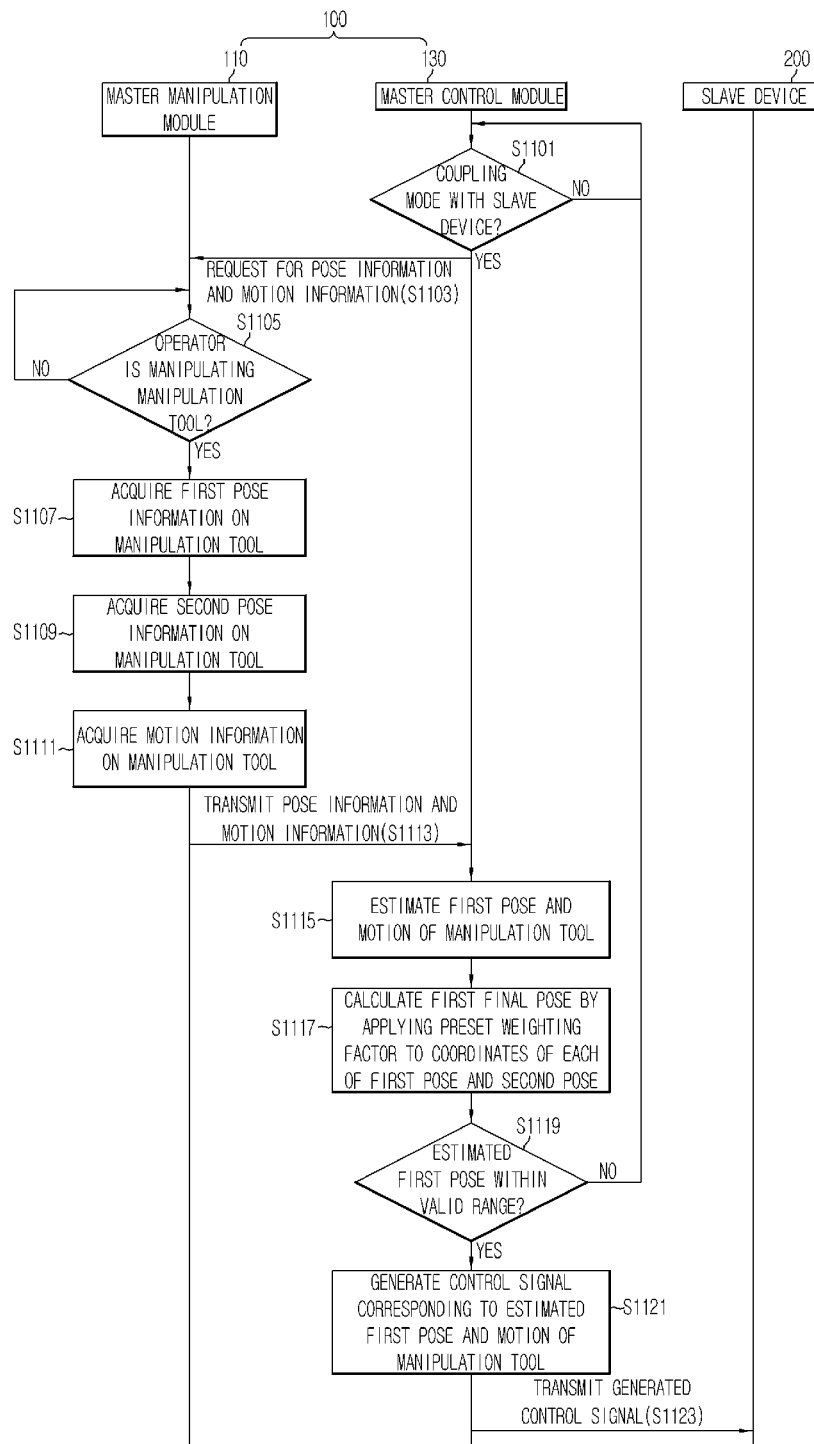
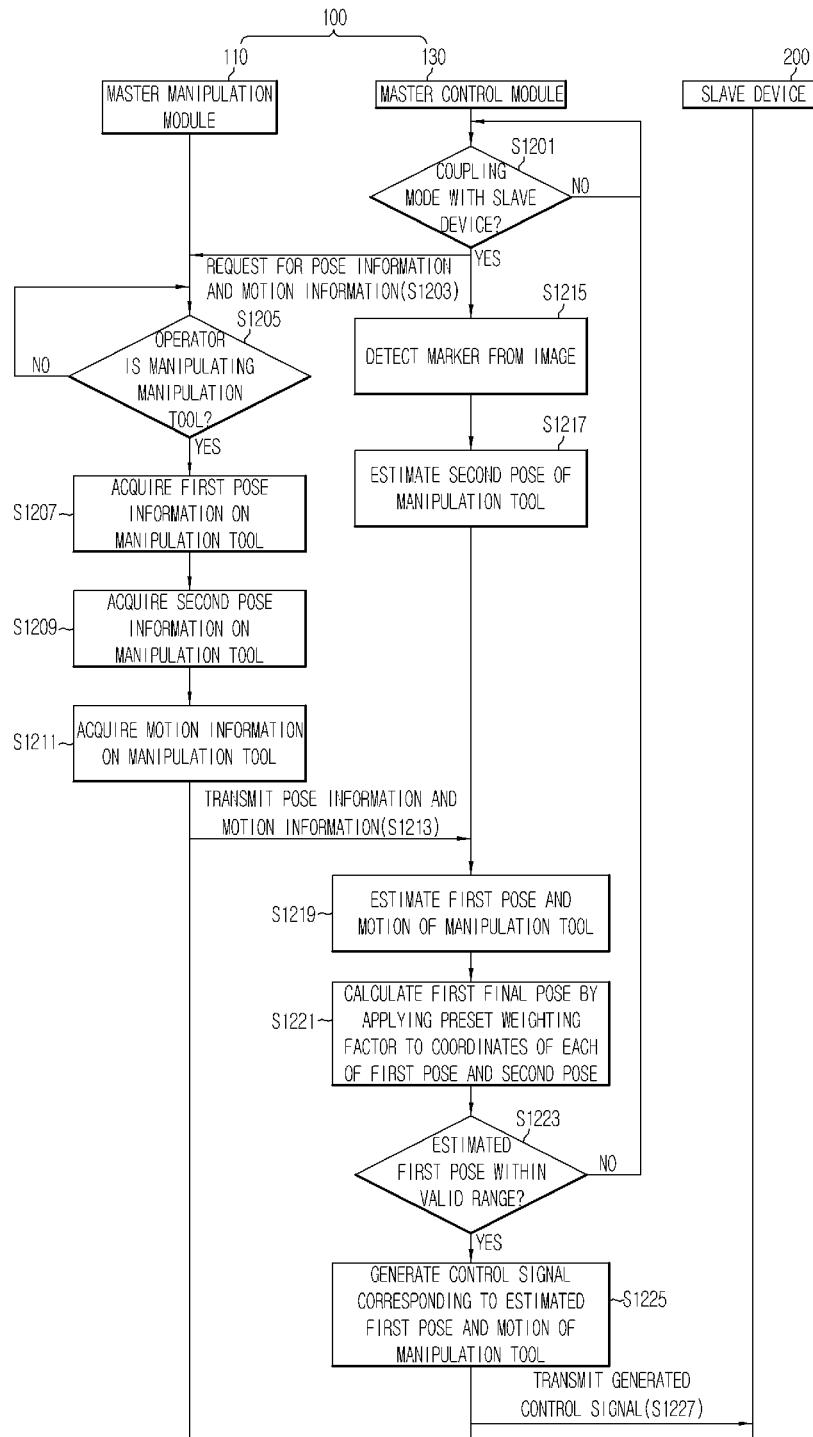


FIG. 12



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SURGICAL ROBOT SYSTEM**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims the priority benefit of Korean Patent Applications No. 10-2013-0037938, filed on Apr. 8, 2013 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND**1. Field**

The following description relates to a surgical robot system that has less workspace restriction and provides intuitive operator manipulation.

2. Description of the Related Art

Minimally invasive surgery refers to surgical methods to minimize the size of an incision. A laparotomy uses a relatively large surgical incision through a part of a human body (e.g., the abdomen). However, in minimally invasive surgery, after forming at least one small port (or incision) of 0.5 cm-1.5 cm through the abdominal wall, an operator inserts an endoscope and a variety of surgical instruments through the port, to perform surgery while viewing an image.

Compared to laparotomy, minimally invasive surgery has several advantages, such as low pain after surgery, early recovery, early restoration of an ability to eat, short hospitalization, rapid return to daily life, and superior cosmetic effects due to a small incision. Accordingly, minimally invasive surgery has been used in gall resection, prostate cancer, and herniotomy operations, etc, and the use thereof continues to expand.

In general, a surgical robot system used in minimally invasive surgery includes a master device and a slave device. The master device generates a control signal corresponding to manipulation of an operator (e.g., a doctor) to transmit the control signal to the slave device. The slave device receives the control signal from the master device to perform manipulation required for surgery of a patient. The master device and the slave device may be integrated with each other, or may be separately arranged in an operating room.

The master device may include an input unit that is manipulated by the operator. The operator may remotely control surgical motion of the slave device by manipulating the input unit. Here, if collision between surgical instruments provided at the slave device occurs, force feedback corresponding to the collision may be provided to the input unit to assist the operator in sensing the occurrence of the collision between the surgical instruments of the slave device. To this end, it may be necessary to mechanically connect the input unit to the master device, which restricts a workspace of the operator. In addition, the input unit generally has a different shape from conventional surgical instruments, and the operator may need to expend considerable time to become proficient in manipulation of the input unit.

SUMMARY

It is an aspect of the present disclosure to provide a surgical robot system that has less workspace restriction and provides intuitive operator manipulation.

Additional aspects of the disclosure will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

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In accordance with an aspect of the disclosure, in a surgical robot system including a slave device having a surgical instrument and a master device to control motion of the surgical instrument, the master device includes a master manipulation module having a manipulation tool, to which a pose recognizer is attached, and a master control module that estimates a pose of the manipulation tool using pose information acquired via the pose recognizer, generates a surgical instrument pose control signal corresponding to the estimated pose of the manipulation tool, and transmits the control signal to the slave device.

In accordance with an aspect of the disclosure, a method for controlling motion of a surgical instrument in a robotic slave device includes detecting, using an motion sensor in a master device, pose information of a manipulation tool in the master device, estimating, in the master device, a pose of the manipulation tool using the detected pose information, generating, in the master device, a surgical instrument pose control signal corresponding to the estimated pose of the manipulation tool, and transmitting the control signal to the robotic slave device.

The motion sensor may include a camera, and the motion sensor detects the pose information of the manipulation tool using the camera.

The manipulation tool may include a marker, and the motion sensor may detect the pose information of the manipulation tool using the camera to detect the marker.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects of the disclosure will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a view showing an outer appearance of a surgical robot system;

FIG. 2 is a perspective view showing a master device of FIG. 1 in detail;

FIG. 3 is a view showing a master manipulation module in detail;

FIG. 4 is a schematic block diagram showing components of the surgical robot system;

FIG. 5 is a block diagram showing an example in which a master device of FIG. 4 further includes a camera;

FIG. 6 is a block diagram showing an example in which a master manipulation module of

FIG. 4 further includes an RF reception node and a master device further includes an RF transmission node;

FIG. 7 is a block diagram showing an example in which the master device of FIG. 6 further includes a camera;

FIG. 8 is a block diagram showing an example in which the master manipulation module of FIG. 7 further includes a vibration motor and a motor drive unit;

FIG. 9 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 4;

FIG. 10 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 5;

FIG. 11 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 6; and

FIG. 12 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 7.

DETAILED DESCRIPTION

Aspects, specific advantages and novel features of the embodiments of the present disclosure will become apparent with reference to the following detailed description and

embodiments described below in detail in conjunction with the accompanying drawings. It is noted that the same or similar elements are denoted by the same reference numerals even though they are depicted in different drawings. In addition, a detailed description of well-known techniques may be omitted to avoid unnecessarily obscuring the present disclosure. Herein, the terms first, second, etc. are used simply to discriminate any one element from other elements, and the elements are not limited to these terms.

Hereinafter, reference will now be made in detail to the embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

FIG. 1 is a view showing an outer appearance of a surgical robot system, FIG. 2 is a perspective view showing a master device of FIG. 1 in detail, FIG. 3 is a view showing a master manipulation module in detail, and FIG. 4 is a schematic block diagram showing components of the surgical robot system.

Referring to FIG. 1, the surgical robot system may include a slave device 200 to perform surgery on a patient P who lies on an operating table, and a master device 100 to assist an operator S (e.g., a doctor) in remotely controlling the slave device 200. In this case, as exemplarily shown in FIG. 1, at least one assistant A, who assists the operator S, may be located near the patient P.

Here, assisting the operator S may refer to assisting surgery by the operator S in a space where the patient P is located. This assistance may include an action such as changing used surgical instruments, for example, but is not limited thereto. For example, various surgical instruments may be used according to the kind of surgery and the number of robot arms 210 provided on the slave device 200, and consequently, the number of surgical instruments used at once may be limited. Accordingly, to change surgical instruments during surgery, the operator S may instruct the assistant A near the patient P to change surgical instruments, and the assistant A may remove the surgical instrument 220 from the robot arm 210 of the slave device 200 according to the operator's instruction and may mount another surgical instrument 220' placed on a tray to the corresponding robot arm 210.

The master device 100 and the slave device 200 may be physically separate devices, without being in any way limited thereto. In one example, the master device 100 and the slave device 200 may be integrated with each other.

As exemplarily shown in FIG. 1, the master device 100 according to the present embodiment may include a master manipulation module 110 and a master control module 130.

The master manipulation module 110 is manipulated by the operator S to generate a control signal for control of motion of surgical instruments 220 of the slave device 200. The master manipulation module 110 may include a manipulation tool T that the operator S grips for manipulation, and a pose recognizer attached to the manipulation tool T to acquire pose information on the manipulation tool T during movement of the manipulation tool T. Here, "pose information" may include a position in a 3-Dimensional (3D) space as well as a pose.

The master control module 130 may serve to estimate a pose of the manipulation tool T based on pose information acquired via the aforementioned pose recognizer, generate a signal to control a pose of the surgical instruments 220 corresponding to the estimated pose, and transmit the control signal to the slave device 200.

In the present embodiment, the master manipulation module 110 and the master control module 130 may be physi-

cally separate devices, without being in any way limited thereto. With this configuration, as compared to a conventional input device physically connected to a main body of a master device, the operator S may implement more convenient manipulation and be less limited with regard to a workspace.

The master manipulation module 110 and the master control module 130, which are physically separate devices, may transmit and receive data via wireless communication. To this end, the master manipulation module 110 and the master control module 130 may include RF transmission/reception units 116 and 134 respectively. The master manipulation module 110 may further include a power source unit 112 to supply power to all components included in the master manipulation module 110 (see FIG. 4). In this case, the power source unit 112 may include a battery, for example, without being in any way limited thereto.

Hereinafter, components and operations of the master manipulation module 110 and the master control module 130 will be described in detail.

The master manipulation module 110, as exemplarily shown in FIGS. 3 and 4, may include the manipulation tool T having handles TH and a body TB, the pose recognizer provided at the manipulation tool T to acquire pose information on the manipulation tool T, the RF transmission/reception unit 116 that transmits and receives data to and from the master control module 130 in a wireless manner, and a first controller 111 that acquires pose information on the manipulation tool T via driving of the pose recognizer and transmits the acquired pose information to the master control module 130 through the RF transmission/reception unit 116.

The manipulation tool T may have the same shape as a surgical instrument that is used by a doctor in a conventional operating setting, without being in any way limited thereto. Here, the surgical instrument may include a knife, scissors, forceps, a cautery, or tweezers, for example, without being in any way limited thereto. That is, the master manipulation module 110 may be constructed by mounting the pose recognizer, the RF transmission/reception unit 116, and the first controller 111 to the manipulation tool T having the same shape as the aforementioned surgical instrument used in a conventional operating setting. In this case, the master manipulation module 110 may be provided in the same number as the surgical instrument used in a conventional operating site.

Accordingly, the operator S, as exemplarily shown in FIG. 2, may skillfully manipulate the manipulation tool T as if the operator were using a conventional surgical instrument, which enables intuitive manipulation and may reduce time required to be skillful in manipulation of the manipulation tool T.

Referring to FIG. 2, both master manipulation modules 110 that the operator grips by both hands may have the same shape. However, it will be clearly understood that the operator S may grip and manipulate different shapes of master manipulation modules 110 by both hands respectively. For example, the operator S may grip and manipulate a scissors-shaped master manipulation module 110 by one hand and a knife-shaped manipulation module 110 by the other hand. Furthermore, although two master manipulation modules 110 are illustrated, the disclosure is not limited thereto. For example, only one master manipulation module 110 may be provided or three master manipulation modules 110 may be provided.

In the present embodiment, various devices may be used as the aforementioned pose recognizer. In a first example, as

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exemplarily shown in FIG. 4, an inertial measurement unit (IMU) 113 may be used. Here, the inertial measurement unit 113 is comprised of a plurality of inertial sensors including an accelerometer and a gyroscope for measurement of angular velocity. In general, the inertial measurement unit 113 may be constructed in such a way that three accelerometers and three gyroscopes are orthogonally arranged. The inertial measurement unit 113 having the aforementioned configuration may measure and output inertia data (hereinafter referred to as first pose information) depending on movement of an object to be measured. Here, the first pose information may refer to information that may be used to estimate a first pose of the manipulation tool T. Specifically, the inertial measurement unit 113 may measure, e.g., movement inertia, rotational inertia, and geomagnetism of the object to be measured, and output first pose information on the object including various information, such as acceleration, velocity, orientation, and distance, for example. The first pose information output from the inertial measurement unit 113 may be transmitted to the first controller 111, and the first controller 111 may transmit the first pose information to the master control module 130.

Specifically, if the operator S manipulates the manipulation tool T to which the inertial measurement unit 113 is attached, the first controller 111 may drive the inertial measurement unit 113 to acquire first pose information (e.g., acceleration, velocity, orientation, and distance) on the manipulation tool T, and transmit the acquired first pose information to the master control module 130 through the RF transmission/reception unit 116.

Alternatively, the aforementioned pose recognizer, as exemplarily shown in FIG. 6, may further include an RF reception node 117. As such, the master device 100 may include a plurality of RF transmission nodes 150 as exemplarily shown in FIGS. 2 and 6. In this case, the plurality of RF transmission nodes 150, as exemplarily shown in FIG. 6, may include a first RF transmission node 151, a second RF transmission node 152, and a third RF transmission node 153, which contain different identification information. Although FIGS. 2 and 6 show the master device 100 as including three RF transmission nodes 150, this is but one embodiment, and the number of RF transmission nodes is not in any way limited thereto.

The RF transmission nodes 151, 152, and 153, as exemplarily shown in FIG. 2, may have a triangular arrangement about the operator S, without being in any way limited thereto. With this arrangement of the RF transmission nodes 151, 152, and 153, distances between the manipulation tool T and the respective RF transmission nodes 151, 152, and 153 may be calculated based on intensities of signals transmitted from the respective RF transmission nodes 151, 152, and 153. As such, pose information on the manipulation tool T (hereinafter referred to as second pose information) may be easily acquired by subjecting the calculated distances to triangulation. The “second pose information” may be used later to estimate a third pose of the manipulation tool T.

More specifically, the first controller 111 of the master manipulation module 110 may control the RF reception node 117 to request signal transmission of the respective RF transmission nodes 151, 152, and 153, and may control the respective RF transmission nodes 151, 152, and 153 to transmit their own identification information to the RF reception node 117 when received the request from the RF reception node 117. Thereafter, the first controller 111 may acquire second pose information on the manipulation tool T based on identification information per RF transmission node 151, 152, or 153 and signal intensity information

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transmitted from the RF reception node 117, and transmit the acquired second pose information to the master control module 130 through the RF transmission/reception unit 116.

In the present embodiment, the aforementioned pose recognizer may include the inertial measurement unit 113 alone, or may include both the inertial measurement unit 113 and the RF reception node 117. Provision of both the inertial measurement unit 113 and the RF reception node 117 may more advantageously correct error that may occur as measurement proceeds as compared to the case in which the inertial measurement unit 113 is used alone.

The master manipulation module 110 according to the present embodiment, as exemplarily shown in FIG. 3, may further include at least one marker M attached to the manipulation tool T, and the master device 100 may further include a camera 170 to acquire an image of the manipulation tool T. In addition, the master control module 130 may detect the marker M from the image of the manipulation tool T acquired via the camera 170, and estimate a pose of the manipulation tool T (hereinafter referred to as a second pose) based on the detected marker M. In this case, the camera 170 may be a depth camera, without being in any way limited thereto. Here, the “depth camera” may refer to a camera that calculates a distance to an object (in the present embodiment, the manipulation tool T) by emitting laser or infrared light to the object and receiving the reflected light, thereby estimating depth information of the object. The depth camera may advantageously acquire a high-resolution image and estimate a depth on a per pixel basis, and apply the acquired information to 3D model generation of a dynamic object or scene.

The second pose of the manipulation tool T may be estimated based on the depth information of each marker M detected using the depth camera.

The master modulation module 110 according to the present embodiment, as exemplarily shown in FIGS. 3 and 4, may further include a motion sensor 115 attached to the manipulation tool T. The motion sensor 115 serves to acquire motion information on the manipulation tool T. In the present embodiment, provision of the motion sensor 115 may be limited to the manipulation tool T that mainly performs spreading and closing motions, for example, scissors and tweezers, without being in any way limited thereto. More specifically, the manipulation tool T, such as scissors and tweezers, as exemplarily shown in FIG. 3, may include a joint, and perform spreading and closing motions according to movement of the joint. As the motion sensor 115 is attached to the corresponding joint, information on motion of the joint (hereinafter referred to as motion information) may be detected. Although the motion sensor 115 may include a potentiometer, the present embodiment is not limited thereto, and other known motion sensors may be used.

More specifically, the first controller 111 of the master manipulation module 110 may acquire motion information on the manipulation tool T by driving the motion sensor 115 attached to the joint of the manipulation tool T, and transmit the acquired motion information to the master control module 130 through the RF transmission/reception unit 116. The master control module 130 may estimate motion of the manipulation tool T based on the motion information transmitted from the master manipulation module 130, generate a surgical instrument motion control signal corresponding to the estimated motion, and transmit the control signal to the slave device 200.

As exemplarily shown in FIGS. 3 and 4, the master manipulation module 110 according to the present embodi-

ment may further include a contact sensor **114** provided at each handle TH of the manipulation tool T. The contact sensor **114** serves to detect whether or not the operator S is manipulating the manipulation tool T, i.e. whether or not the operator S is gripping the manipulation tool T. In the present embodiment, through provision of the aforementioned contact sensor **114**, if an unexpected situation, such as a situation that the operator S is not gripping the manipulation tool T or drops the manipulation tool T during surgery, occurs, no control signal corresponding to pose information and motion information on the manipulation tool T is transmitted to the slave device **200**, which may prevent accidents in an unexpected situation.

Although the contact sensor **114** may be attached to an inner wall of the handle TH that directly comes into contact with the hand of the operator S, a position of the contact sensor **114** is not in any way limited thereto and the contact sensor **114** may be provided anywhere so long as the contact sensor **114** may come into contact with the hand of the operator S. In addition, in the present embodiment, the contact sensor **114** may be a sensor that detects contact based on capacitance variation, without being in any way limited thereto.

As exemplarily shown in FIG. **8**, the master manipulation module **110** according to the present embodiment may further include a vibration motor **118** provided at the manipulation tool T, and a motor drive unit **119** to drive the vibration motor **118**. This configuration serves to inform the operator S of occurrence of a situation that the surgical instrument **220** of the slave device **200** collides with any internal organ or tissue during surgery. The first controller **111** of the master manipulation module **110** drives the vibration motor **118** using the motor drive unit **119** upon receiving a signal indicating the aforementioned situation from the slave device **200**, thereby controlling the manipulation tool T to vibrate. As such, the operator S may sense a collision of the surgical instrument **220** of the slave device **200**.

The master control module **130** according to the present embodiment, as exemplarily shown in FIGS. **1** and **4**, may include the RF transmission/reception unit **134** that transmits and receives data to and from the master manipulation module **110** in a wireless manner, a manipulation tool pose estimation unit **133** that estimates a pose of the manipulation tool T based on pose information on the manipulation tool T transmitted through the RF transmission/reception unit **134**, and a second controller **131** that determines whether or not the estimated pose is within a valid range, generates a surgical instrument pose control signal corresponding to the estimated pose if the estimated pose is within the valid range, and transmits the control signal to the slave device **200**. Here, the "valid range" is a predetermined workspace range of the manipulation tool T. If the estimated pose deviates from the valid range, an abnormal manipulation situation is judged, and thus the surgical instrument pose control signal corresponding to the pose of the manipulation tool T is not generated.

The master device **100** may further include the camera **170** as described above, and the second controller **131** may detect the marker M from the image of the manipulation tool T acquired via the camera **170**, and estimate a pose of the manipulation tool T based on the detected marker M.

More specifically, the second controller **131** of the master control module **130** may estimate a pose of the manipulation tool T based on pose information on the manipulation tool T transmitted from the master manipulation module **110**, or may estimate a pose of the manipulation tool T using the

image acquired via the camera **170**. Hereinafter, for convenience of description, a pose of the manipulation tool T estimated based on pose information transmitted from the master manipulation module **110** may be referred to as a first pose (i.e. a pose estimated based on first pose information acquired by the inertial measurement unit **113**) or a third pose (i.e. a pose estimated based on second pose information acquired by the RF reception node **117**), and a pose of the manipulation tool T estimated using the marker M detected from the image acquired via the camera **170** may be referred to as a second pose.

The pose information on the manipulation tool T transmitted from the master manipulation module **110** may include first pose information acquired via the inertial measurement unit **113** provided at the manipulation tool T and second pose information acquired via the RF reception node **117**. In this case, only the first pose information may be transmitted, only the second pose information may be transmitted, or both the first pose information and the second pose information may be transmitted.

In the case in which only one of the first pose information or the second pose information is transmitted, the second controller **131** may estimate a pose of the manipulation tool T (a first pose or a third pose) based on the transmitted only one unit of pose information. On the other hand, in the case in which both the first pose information and the second pose information are transmitted, the second controller **131** may estimate two poses, i.e. a first pose and a third pose of the manipulation tool T. In addition, as described above, in the case in which the marker M is attached to the manipulation tool T and the camera **170** is provided, the second controller **131** may estimate a second pose of the manipulation tool T using the image acquired via the camera **170**.

In the present embodiment, the aforementioned components may be used alone, or may be combined with each other. For example, a configuration including only the inertial measurement unit **113** may be realized (see FIG. **4**), a configuration including the inertial measurement unit **113**, the RF reception node **117** and the RF transmission node **150** may be realized (see FIG. **6**), and a configuration including the marker M, the camera **170**, the RF reception node **117** and the RF transmission node **150** may be realized (see FIG. **7**). Here, combination of two or more components may ensure more accurate pose calculation via correction of error that may occur upon estimation of a pose of the manipulation tool T based on only one unit of pose information.

Hereinafter, operation of the second controller **131** with regard to the embodiments will be described.

According to an embodiment, the second controller **131** may estimate a first pose of the manipulation tool T based on first pose information transmitted via the manipulation tool pose estimation unit **133**, determine whether or not the estimated first pose is within a valid range, generate a surgical instrument pose control signal corresponding to the estimated first pose using a control signal generator **135** if the first pose is within the valid range, and transmit the generated surgical instrument pose control signal to the slave device **200** through a communication unit **140**.

According to an embodiment, the second controller **131** may estimate a first pose of the manipulation tool T based on first pose information transmitted via the manipulation tool pose estimation unit **133**, and a second pose of the manipulation tool T based on depth information of the marker M detected from the image of the manipulation tool T acquired

via the camera 170. Thereafter, the second controller 131 may calculate a first final pose of the manipulation tool T by applying a predetermined weighting factor w to coordinates of each of the estimated first pose and second pose, determine whether or not the calculated first final pose is within a valid range, generate a surgical instrument pose control signal corresponding to the calculated first final pose using the control signal generator 135 if the first final pose is within the valid range, and transmit the generated surgical instrument pose control signal to the slave device 200 through the communication unit 140.

According to an embodiment, the second controller 131 may estimate a first pose and a third pose of the manipulation tool T based on first pose information and second pose information transmitted via the manipulation tool pose estimation unit 133. Thereafter, the second controller 131 may calculate a second final pose of the manipulation tool T by applying a predetermined weighting factor w to coordinates of each of the estimated first pose and third pose, determine whether or not the calculated second final pose is within a valid range, generate a surgical instrument pose control signal corresponding to the calculated second final pose using the control signal generator 135 if the second final pose is within the valid range, and transmit the generated surgical instrument pose control signal to the slave device 200 through the communication unit 140.

According to an embodiment, the second controller 131 may estimate a first pose and a third pose of the manipulation tool T based on first pose information and second pose information transmitted via the manipulation tool pose estimation unit 133, and additionally estimate a second pose of the manipulation tool T based on depth information of the marker M detected from the image of the manipulation tool T acquired via the camera 170. Thereafter, the second controller 131 may calculate a third final pose of the manipulation tool T by applying a predetermined weighting factor w to coordinates of each of the estimated first pose, second pose, and third pose, determine whether or not the calculated third final pose is within a valid range, generate a surgical instrument pose control signal corresponding to the calculated third final pose using the control signal generator 135 if the third final pose is within the valid range, and transmit the generated surgical instrument pose control signal to the slave device 200 through the communication unit 140.

The master control module 130 according to the present embodiment may further include a manipulation tool motion estimation unit 132 to estimate motion of the manipulation tool T based on motion information transmitted from the master manipulation module 110. Specifically, the second controller 131 may estimate motion of the manipulation tool T based on motion information transmitted from the master manipulation module 110 using the manipulation tool motion estimation unit 132. Thereafter, the second controller 131 may generate a surgical instrument motion control signal corresponding to the estimated motion using the control signal generator 135, and transmit the generated surgical instrument motion control signal to the slave device 200 through the communication unit 140.

The master device 100 according to the present embodiment, as exemplarily shown in FIG. 4, may further include a mode input unit 160. The mode input unit 160 serves to set a connection between the master device 100 and the slave device 200. For example, the mode input unit 160 may take the form of a pedal, a switch, or a button, for example, without being in any way limited thereto. The mode input unit 160 may be positioned so as to be manipulated by foot

of the operator S because the operator S manipulates the master manipulation mode 110 by hand, but a position of the mode input unit 160 is not limited thereto. Through use of the mode input unit 160, the master device 100 and the slave device 200 may be set to a coupling mode, a decoupling mode, or an end mode, for example. Transmission of a control signal from the master device 100 to the slave device 200 may be accomplished only in the coupling mode.

Hereinafter, operations of the surgical robot system including the aforementioned components will be described. More specifically, FIG. 9 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 4 according to an embodiment, FIG. 10 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 5 according to an embodiment, FIG. 11 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 6 according to an embodiment, and FIG. 12 is a flowchart showing operations of the respective components of the surgical robot system of FIG. 7 according to an embodiment.

Referring to FIG. 9, in the surgical robot system of FIG. 4 according to an embodiment, whether or not the master control module 130 and the slave device 200 are in a coupling mode is judged (operation S901). If the coupling mode is judged, the master control module 130 transmits a signal to request the master manipulation module 110 of pose information and motion information on the manipulation tool T (operation S903). In this case, the aforementioned request signal may be transmitted in a wireless manner through the RF transmission/reception unit 134.

Next, the master manipulation module 110, which has received the pose information and motion information request signal from the master control module 130, determines whether or not the operator S is manipulating the manipulation tool T (operation S905). If the operator S is manipulating the manipulation tool T, the master manipulation module 110 acquires first pose information on the manipulation tool T using the inertial measurement unit 113 attached to the manipulation tool T (operation S907). In this case, whether or not the operator S is manipulating the manipulation tool T may be judged via the contact sensor 114 provided at each handle TH of the manipulation tool T, without being in any way limited thereto.

Next, the master manipulation module 110 acquires motion information on the manipulation tool T using the motion sensor 115 provided at the joint of the manipulation tool T (operation S909), and thereafter transmits first pose information on the manipulation tool T acquired in operation S907 as well as the acquired motion information to the master control module 130 (operation S911).

Next, the master control module 130 estimates a first pose and motion of the manipulation tool T based on the first pose information and motion information transmitted from the master manipulation module 110 (operation S913), and determines whether or not the estimated first pose is within a valid range (operation S915). If the judged result shows that the first pose is within the valid range, the master control module 130 generates a surgical instrument pose control signal and a surgical instrument motion control signal corresponding respectively to the estimated first pose and motion (operation S917), and transmits the surgical instrument pose control signal and the surgical instrument motion control signal to the slave device 200 (operation S919). Here, the "valid range" may be a predetermined workspace range of the manipulation tool T, for example.

Although operations after transmission of the surgical instrument pose control signal and the surgical instrument

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motion control signal to the slave device **200** (operation **S919**) are not shown in FIG. **9**, it will be clearly understood that the slave device **200** may control a pose and motion of the surgical instrument **220** based on the surgical instrument pose control signal and the surgical instrument motion control signal transmitted from the master device **100**.

Referring to FIG. **10**, in the surgical robot system of FIG. **5** according to an embodiment, whether or not the master control module **130** and the slave device **200** are in a coupling mode is judged (operation **S1001**). If the coupling mode is judged, the master control module **130** requests the master manipulation module **110** of pose information and motion information on the manipulation tool **T** (operation **S1003**), detects the marker **M** from the image of the manipulation tool **T** acquired via the camera **170** (operation **S1013**), and estimates a second pose of the manipulation tool **T** based on depth information of the detected marker **M** (operation **S1015**).

Next, the master manipulation module **110**, which has received the pose information and motion information request signal from the master control module **130**, determines whether or not the operator **S** is manipulating the manipulation tool **T** (operation **S1005**). If the operator **S** is manipulating the manipulation tool **T**, the master manipulation module **110** acquires first pose information on the manipulation tool **T** using the inertial measurement unit **113** attached to the manipulation tool **T** (operation **S1007**). In this case, whether or not the operator **S** is manipulating the manipulation tool **T** may be judged via the contact sensor **114** provided at each handle **TH** of the manipulation tool **T**, without being in any way limited thereto.

Next, the master manipulation module **110** acquires motion information on the manipulation tool **T** using the motion sensor **115** provided at the joint of the manipulation tool **T** (operation **S1009**), and thereafter transmits first pose information on the manipulation tool **T** acquired in operation **S1007** as well as the acquired motion information to the master control module **130** (operation **S1011**).

Next, the master control module **130** estimates a first pose and motion of the manipulation tool **T** based on the first pose information and motion information transmitted from the master manipulation module **110** (operation **S1017**), calculates a first final pose of the manipulation tool **T** by applying a predetermined weighting factor **w** to coordinates of each of the estimated first pose and the second pose estimated in operation **S1015** (operation **S1019**), determines whether or not the calculated first final pose is within a valid range (operation **S1021**), generates a surgical instrument pose control signal and a surgical instrument motion control signal corresponding respectively to the calculated first final pose and the estimated motion if the first final pose is within the valid range (operation **S1023**), and transmits the surgical instrument pose control signal and the surgical instrument motion control signal to the slave device **200** (operation **S1025**).

Referring to FIG. **11**, in the surgical robot system of FIG. **6** according to an embodiment, whether or not the master control module **130** and the slave device **200** are in a coupling mode is judged (operation **S1101**). If the coupling mode is judged, the master control module **130** transmits a signal to request the master manipulation module **110** of pose information and motion information on the manipulation tool **T** (operation **S1103**). In this case, the aforementioned request signal may be transmitted in a wireless manner through the RF transmission/reception unit **134**.

Next, the master manipulation module **110**, which has received the pose information and motion information

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request signal from the master control module **130**, determines whether or not the operator **S** is manipulating the manipulation tool **T** (operation **S1105**). If the operator **S** is manipulating the manipulation tool **T**, the master manipulation module **110** acquires first pose information on the manipulation tool **T** using the inertial measurement unit **113** attached to the manipulation tool **T** (operation **S1107**), and acquires second pose information on the manipulation tool **T** using the RF reception node **117** provided at the manipulation tool **T** and the RF transmission node **150** provided near the operator **S** (operation **S1109**).

Next, the master manipulation module **110** acquires motion information on the manipulation tool **T** using the motion sensor **115** provided at the joint of the manipulation tool **T** (operation **S1111**), and transmits the acquired motion information as well as the first pose information and the second pose information acquired respectively in operation **S1107** and operation **S1109** to the master control module **130** (operation **S1113**).

Next, the master control module **130** estimates a first pose, a third pose, and motion of the manipulation tool **T** based on the first pose information, the second pose information, and motion information transmitted from the master manipulation module **110** (operation **S1115**), and calculates a second final pose of the manipulation tool **T** by applying a predetermined weighting factor **w** to coordinates of each of the estimated first pose and third pose (operation **S1117**).

Next, the master control module **130** determines whether or not the calculated second final pose is within a valid range (operation **S1119**), generates a surgical instrument pose control signal and a surgical instrument motion control signal corresponding respectively to the calculated second final pose and the estimated motion if the second final pose is within the valid range (operation **S1121**), and transmits the surgical instrument pose control signal and the surgical instrument motion control signal to the slave device **200** (operation **S1123**).

Referring to FIG. **12**, in the surgical robot system of FIG. **7** according to an embodiment, whether or not the master control module **130** and the slave device **200** are in a coupling mode is judged (operation **S1201**). If the coupling mode is judged, the master control module **130** requests the master manipulation module **110** of pose information and motion information on the manipulation tool **T** (operation **S1203**), detects the marker **M** from the image of the manipulation tool **T** acquired via the camera **170** (operation **S1215**), and estimates a second pose of the manipulation tool **T** based on depth information of the detected marker **M** (operation **S1217**).

In addition, the master manipulation module **110**, which has received the signal to request for pose information and motion information from the master control module **130**, acquires first pose information on the manipulation tool **T** using the inertial measurement unit **113** attached to the manipulation tool **T** (operation **S1207**), acquires second pose information on the manipulation tool **T** using the RF reception node **117** provided at the manipulation tool **T** and the RF transmission node **150** provided near the operator **S** (operation **S1209**), acquires motion information on the manipulation tool **T** using the motion sensor **115** provided at the joint of the manipulation tool **T** (operation **S1211**), and transmits the acquired motion information as well as the first pose information and the second pose information acquired respectively in operation **S1207** and **S1209** to the master control module **130** (operation **S1213**).

Next, the master control module **130** estimates a first pose, a third pose, and motion of the manipulation tool **T**

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based on the first pose information, the second pose information, and motion information transmitted from the master manipulation module **110** (operation **S1219**), calculates a third final pose of the manipulation tool **T** by applying a predetermined weighting factor **w** to coordinates of each of the estimated first pose and third pose as well as the second pose estimated in operation **S1217** (operation **S1221**), determines whether or not the calculated third final pose is within a valid range (operation **S1223**), generates a surgical instrument pose control signal and a surgical instrument motion control signal corresponding respectively to the calculated third final pose and the estimated motion if the third final pose is within the valid range (operation **S1225**), and transmits the surgical instrument pose control signal and the surgical instrument motion control signal to the slave device **200** (operation **S1227**).

As described above, there are various embodiments with regard to configurations for estimation of a pose of the manipulation tool **T** that generates a control signal to control a pose of the surgical instrument **220** of the slave device **200**. Although any one configuration may be used alone, two or more configurations may be combined with one another, which may ensure more accurate estimation of a pose of the manipulation tool **T** via correction of error that may occur when adopting only one configuration.

The master device **100** according to the present embodiment, as exemplarily shown in FIG. **4**, may further include the communication unit **140**. The communication unit **140** serves to transmit and receive data between the master device **100** and the slave device **200**, and may perform wired communication, wireless communication, or a combination thereof.

As exemplarily shown in FIG. **4**, the master device **100** may further include a display unit **120**. The display unit **120** may display an image of the interior of the patient's body collected via an endoscope **230** of the slave device **200**, and a 3D virtual image acquired using medical images of the patient **P** before surgery. To this end, the master device **100** may include an image processor **136** that receives and processes image data transmitted from the slave device **200** to output the image data to the display unit **120**. Here, the "image data", as described above, may include an image of the interior of the patient's body collected via the endoscope **230** and a 3D virtual image acquired using medical images of the patient before surgery, without being in any way limited thereto.

In the present embodiment, the display unit **120** may include a Liquid Crystal Display (LCD), a Light Emitting Diode (LED) display, a transparent display, a hologram display, or a Head Mounted Display (HMD), for example, without being in any way limited thereto.

In addition, in the present embodiment, an augmented reality image generated by composing the manipulation tool **T** that is being manipulated by the operator **S** over a corresponding position of the actual image of the interior of the patient's body collected via the endoscope **230** may be displayed on the display unit **120**. As such, the operator **S** may intuitively manipulate the manipulation tool **T** as if the operator were directly performing surgery.

The display unit **120** may display information regarding operation of the slave device **200** as well as patient information, for example. Here, the "patient information" may be information indicating the state of the patient **P**, such as patient vital signs, such as body-temperature, pulse, respiration-rate, blood-pressure, for example. To provide the master device **100** with the vital signs, the slave device **200** that will be described hereinafter may further include a vital

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sign measurement unit including a body-temperature measurement module, a pulse measurement module, a respiration-rate measurement module, a blood-pressure measurement module, etc. The master device **100** may further include a signal processor (not shown) that receives and processes vital signs transmitted from the slave device **200** to output the processed vital signs to the display unit **120**.

The slave device **200**, as exemplarily shown in FIG. **1**, may include a plurality of robot arms **210**, and various surgical instruments **220** mounted at ends of the respective robot arms **210**. The plurality of robot arms **210**, as exemplarily shown in FIG. **1**, may be coupled to a main body **201** to be fixed to and supported by the main body **201**. In this case, the number of the surgical instruments **220** that are used at once as well as the number of the robot arms **210** may depend on various factors, such as diagnostic methods, surgical methods, and spatial restrictions of an operating room.

Each of the plurality of robot arms **210** may include a plurality of links **211** and a plurality of joints **213**. Each joint **213** may connect the two links **211** to each other and may have 1 degree of freedom (DOF) or more. Here, the "DOF" refers to a DOF with regard to kinematics or inverse kinematics, i.e. the DOF of a device. The DOF of a device refers to the number of independent motions of a device, or the number of variables that determine independent motions at relative positions between links. For example, an object in a 3D space defined by X-, Y-, and Z-axes has one or more of 3 DOF to determine a spatial position of the object (a position on each axis), 3 DOF to determine a spatial pose of the object (a position on each axis), and 3 DOF to determine a spatial orientation of the object (a rotation angle relative to each axis). More specifically, it will be appreciated that the object has 6 DOF if an object is movable along each of X-, Y- and Z-axes and is rotatable about each of X-, Y- and Z-axes.

Each joint **213** may be provided with a detector to detect information regarding the state of the joint **213**. For example, the detector may include a force/torque detector to detect information regarding force/torque applied to the joint **213**, a position detector to detect information regarding a position of the joint **213**, and a speed detector to detect information regarding a movement speed of the joint **213**. Here, the speed detector may be omitted according to the kind of a position sensor that is used as the position detector.

Each joint of the robot arm **210** may be provided with a first drive unit **215** to control movement of the robot arm **210** in response to a surgical instrument pose control signal transmitted from the master device **100**. For example, if the operator **S** manipulates the manipulation tool **T** of the master manipulation module **110** of the master device **100**, the first controller **111** of the master manipulation module **110** acquires pose information on the manipulation tool **T** to transmit the acquired pose information to the master control module **130**. The master control module **130** generates a surgical instrument pose control signal corresponding to the transmitted pose information to transmit the control signal to the slave device **200** via a communication unit **260**.

Thereafter, the controller **240** of the slave device **200** drives the first drive unit **215** in response to the surgical instrument pose control signal transmitted from the master device **100**, thereby controlling movement of each joint of the robot arm **210** and moving the surgical instrument **220** mounted to the robot arm **210** to hold a corresponding pose. In this case, a practical procedure of controlling rotation and movement of the robot arm **210** in a given direction in response to the surgical instrument pose control signal

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deviates somewhat from the substance of the disclosure, and thus a detailed description thereof will be omitted herein.

Meanwhile, although each joint of the robot arm **210** of the slave device **200**, as described above, may be moved in response to a control signal transmitted from the master device **100**, the joint may be moved by external force. That is, the assistant A located near an operating table may manually move each joint of the robot arm **210** to control, e.g., a pose of the surgical instrument **220**.

Although not shown in FIG. 1, for example, each surgical instrument **220** may include a housing mounted to the end of the robot arm **210**, a shaft extending from the housing by a predetermined length, and an end effector coupled to a distal end of the shaft.

In general, the surgical instruments **220** may be classified into main surgical instruments and auxiliary surgical instruments. Here, the “main surgical instrument” may refer to an instrument including an end effector (e.g., a knife or a surgical needle) that performs direct surgical motion, such as, e.g., cutting, suturing, clotting, or washing, on a surgical region. The “auxiliary surgical instrument” may refer to an instrument including an end effector (e.g., a skin holder) that does not perform direct motion on a surgical region and assists motion of the main surgical instrument.

The end effector is a part of the surgical instrument **220** that practically acts on a surgical region of the patient P. For example, the end effector may include a skin holder, suction line, knife, scissors, grasper, surgical needle, staple applier, needle holder, scalpel, cutting blade, etc., without being in any way limited thereto. Any other known instruments required for surgery may be used.

A drive wheel may be coupled to the housing and connected to the end effector via a wire, for example. Thus, the end effector may be operated via rotation of the drive wheel. To this end, a second drive unit **225** to rotate the drive wheel may be provided at the end of the robot arm **210**. For example, if the operator S manipulates the manipulation tool T of the master manipulation module **110** of the master device **100**, the first controller **111** of the master manipulation module **110** acquires motion information on the manipulation tool T to transmit the information to the master control module **130**, and the master control module **130** generates a surgical instrument motion control signal corresponding to motion information transmitted from the master control module **130** to transmit the control signal to the slave device **200**.

Thereafter, as the controller **240** of the slave device **200** drives the second drive unit **225** in response to the surgical instrument motion control signal transmitted from the master device **100**, desired motion of the end effector may be realized. However, a mechanism to operate the end effector is not limited to the aforementioned configuration and various electrical/mechanical mechanisms may naturally be applied to realize motion of the end effector required for robotic surgery.

The endoscope **230** of the slave device **200** serves to assist motion of a main surgical instrument rather than directly performing surgical motion on a surgical region. Thus, it will be appreciated that the endoscope **230** corresponds to an auxiliary surgical instrument in a broad sense. The endoscope **230** may be selected from among various surgical endoscopes, such as a thoracoscope, arthroscope, rhinoscope, cystoscope, proctoscope, duodenoscope, and cardioscope, for example, in addition to a celioscope that is mainly used in robotic surgery.

In addition, the endoscope **230** may be a Complementary Metal Oxide Semiconductor (CMOS) camera or a Charge

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Coupled Device (CCD) camera, without being in any way limited thereto. The endoscope **230** may include a lighting device (not shown) to emit light to a surgical region. In addition, the endoscope **230** may be mounted to the end of the robot arm **210** as exemplarily shown in FIG. 1, and the slave device **200** may further include a third drive unit **235** to operate the endoscope **230**. In addition, the controller **240** of the slave device **200** may transmit an image of the interior of the patient's body collected via the endoscope **230** to the master device **100**.

In addition, the slave device **200** may further include a display unit **250** to display an image of the interior of the patient's body collected via the endoscope **230**. To this end, the controller **240** of the slave device **200** may include an image processor **241** that processes an image collected via the endoscope **230** to output the processed image to the display unit **250**.

If the surgical instrument **220** inserted into the patient's body collides with internal organs or tissues, the controller **240** of the slave device **200** may transmit a signal indicating occurrence of collision to the master device **100**.

The above-described embodiments may be recorded in computer-readable media including program instructions to implement various operations embodied by a computer. The media may also include, alone or in combination with the program instructions, data files, data structures, and the like. The program instructions recorded on the media may be those specially designed and constructed for the purposes of embodiments, or they may be of the kind well-known and available to those having skill in the computer software arts. Examples of computer-readable media include magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD ROM disks and DVDs; magneto-optical media such as optical disks; and hardware devices that are specially configured to store and perform program instructions, such as read-only memory (ROM), random access memory (RAM), flash memory, and the like. The computer-readable media may also be a distributed network, so that the program instructions are stored and executed in a distributed fashion. The program instructions may be executed by one or more processors. The computer-readable media may also be embodied in at least one application specific integrated circuit (ASIC) or Field Programmable Gate Array (FPGA), which executes (processes like a processor) program instructions. Examples of program instructions include both machine code, such as produced by a compiler, and files containing higher level code that may be executed by the computer using an interpreter. The above-described devices may be configured to act as one or more software modules in order to perform the operations of the above-described embodiments, or vice versa.

Although the embodiments of the present disclosure have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.

What is claimed is:

1. A surgical robot system comprising:

- a slave device including a surgical instrument; and
- a master device to control motion of the surgical instrument, the master device including,
 - a master manipulation module including,
 - a manipulation tool having a handle and a body, the manipulation tool being a wireless device having a same shape as the surgical instrument controlled thereby,

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a pose recognizer configured to acquire information on a movement of the manipulation tool during the movement of the manipulation tool,

a first Radio Frequency (RF) transmitter/receiver configured to wirelessly transmit data, and

a first controller configured to,

acquire pose information of the manipulation tool by driving the pose recognizer, and

transmit, via the first RF transmitter/receiver, the acquired pose information; and

a master control module configured to,

receive the pose information from the master manipulation module,

estimate a pose of the manipulation tool using the pose information acquired with the pose recognizer,

generate a surgical instrument pose control signal corresponding to the estimated pose of the manipulation tool, and

transmit the control signal to the slave device.

2. The system according to claim 1, wherein the pose recognizer includes an inertial measurement unit, and

the first controller acquires first pose information of the manipulation tool with the inertial measurement unit, and transmits the acquired first pose information to the master control module with the first RF transmitter/receiver.

3. The system according to claim 2, wherein the master control module comprises:

a second RF transmitter/receiver configured to transmit and receive data to and from the master manipulation module in a wireless manner;

a manipulation tool pose estimation unit configured to estimate a first pose of the manipulation tool based on the first pose information transmitted with the second RF transmission/reception unit; and

a second controller configured to determine whether or not the estimated first pose is within a valid range, generate a surgical instrument pose control signal corresponding to the estimated first pose if the first pose is within the valid range, and transmit the surgical instrument pose control signal to the slave device.

4. The system according to claim 3, wherein the valid range is a predetermined workspace range of the manipulation tool.

5. The system according to claim 3, wherein the master manipulation module further includes a plurality of markers formed at the manipulation tool, the master device further includes a camera to acquire an image of the manipulation tool, and the second controller is configured to,

detect the plurality of markers from the image acquired with the camera,

estimate a second pose of the manipulation tool based on the respective detected markers,

calculate a first final pose of the manipulation tool by applying a predetermined weighting factor to coordinates of each of the estimated first pose and second pose,

determine whether or not the calculated first final pose is within a valid range,

generate a surgical instrument pose control signal corresponding to the first final pose if the first final pose is within the valid range, and

transmit the generated surgical instrument pose control signal to the slave device.

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6. The system according to claim 5, wherein the master manipulation module further includes a motion sensor provided at the manipulation tool to acquire motion information on the manipulation tool,

the first controller acquires motion information on the manipulation tool by driving the motion sensor, and transmits the acquired motion information to the master control module with the first RF transmitter/receiver;

the master control module further includes a manipulation tool motion estimation unit to estimate motion of the manipulation tool based on the motion information transmitted from the master manipulation module, and

the second controller generates a surgical instrument motion control signal corresponding to the estimated motion, and transmits the generated surgical instrument motion control signal to the slave device.

7. The system according to claim 2, wherein the pose recognizer further includes an RF reception node,

the master device includes a plurality of RF transmission nodes containing different identification information, and

the first controller acquires second pose information on the manipulation tool based on signal intensity as well as identification information on the plurality of RF transmission nodes transmitted to the RF reception node, and thereafter transmits the acquired first pose information and second pose information to the master control module with the first RF transmission/reception unit.

8. The system according to claim 7, wherein the master control module comprises:

a second RF transmitter/receiver configured to transmit and receive data to and from the master manipulation module in a wireless manner;

a manipulation tool pose estimation unit configured to estimate a first pose and a third pose of the manipulation tool based on the first pose information and the second pose information transmitted with the second RF transmitter/receiver; and

a second controller configured to,

calculate a second final pose by applying a predetermined weighting factor to coordinates of each of the estimated first pose and third pose,

determine whether or not the second final pose is within a valid range,

generate a surgical instrument pose control signal corresponding to the second final pose if the second final pose is within the valid range, and

transmit the generated surgical instrument pose control signal to the slave device.

9. The system according to claim 8, wherein the valid range is a workspace range of the manipulation tool.

10. The system according to claim 8, wherein the master manipulation module further includes a plurality of markers attached to the manipulation tool, the master device further includes a camera to acquire an image of the manipulation tool, and the second controller is configured to,

detect the plurality of markers from the image acquired with the camera, estimates a second pose of the manipulation tool based on the respective detected markers,

calculate a third final pose of the manipulation tool by applying a predetermined weighting factor to coordinates of each of the estimated first pose, second pose and third pose,

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determine whether or not the calculated third final pose is within a valid range,
 generate a surgical instrument pose control signal corresponding to the calculated third final pose if the third final pose is within the valid range, and
 transmit the generated surgical instrument pose control signal to the slave device.

11. The system according to claim 10, wherein the valid range is a predetermined workspace range of the manipulation tool.

12. The system according to claim 10, wherein the master manipulation module further includes a motion sensor provided at the manipulation tool to acquire motion information on the manipulation tool,
 the first controller acquires motion information on the manipulation tool by driving the motion sensor, and transmits the acquired motion information to the master control module with the first RF transmitter/receiver, the master control module further includes a manipulation tool motion estimation unit to estimate motion of the manipulation tool based on the motion information transmitted from the master manipulation module, and the second controller generates a surgical instrument motion control signal corresponding to the estimated motion, and transmits the generated surgical instrument motion control signal to the slave device.

13. The system according to claim 1, wherein the master manipulation module further comprises:

a contact sensor provided at the handle of the manipulation tool, the contact sensor configured to detect whether or not the operator is manipulating the manipulation tool.

14. The system according to claim 1, wherein the master manipulation module further comprises:

a vibration motor provided at the manipulation tool and a motor drive unit to drive the vibration motor, and wherein
 the first controller is configured to drive the vibration motor using the motor drive unit to vibrate the manipulation tool if a signal indicating a collision of the surgical instrument is transmitted from the slave device.

15. The system according to claim 1, wherein the master device further comprises:

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a display unit configured to display a medical image of a patient.

16. The system according to claim 15, wherein the display unit comprises:

at least one of a Liquid Crystal Display (LCD), a Light Emitting Diode (LED) display, a transparent display, a hologram display, and a Head Mounted Display (HMD).

17. The system according to claim 1, wherein the master device further comprises:

a mode input unit configured to set a connection mode with the slave device.

18. The system according to claim 17, wherein the mode input unit comprises:

at least one of a pedal, a switch, and a button.

19. The system according to claim 1, wherein the master manipulation module and the master control module are separated from each other.

20. A method for controlling motion of a surgical instrument in a robotic slave device by a master device, the master device including a master manipulation module and a master control module, the master manipulation module including a manipulation tool, a pose recognizer, a Radio Frequency (RF) transmitter/receiver and a controller, the method comprising:

acquiring, via the pose recognizer, information on a movement of the manipulation tool during the movement of the manipulation tool, the manipulation tool having a handle and a body and being a wireless device having a same shape as the surgical instrument controlled thereby;

acquiring, via the controller, pose information of the manipulation tool by driving the pose recognizer;

wirelessly transmitting, via the RF transmitter/receiver, data including the pose information to the master control module;

estimating, in the master control device, a pose of the manipulation tool using the pose information;

generating, in the master control device, a surgical instrument pose control signal corresponding to the estimated pose of the manipulation tool; and

transmitting the control signal to the robotic slave device.

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